# Retrospective Analog Year Analyses Using NASA Satellite Precipitation and Soil Moisture Data to Improve USDA's World Agricultural Supply and Demand Estimates

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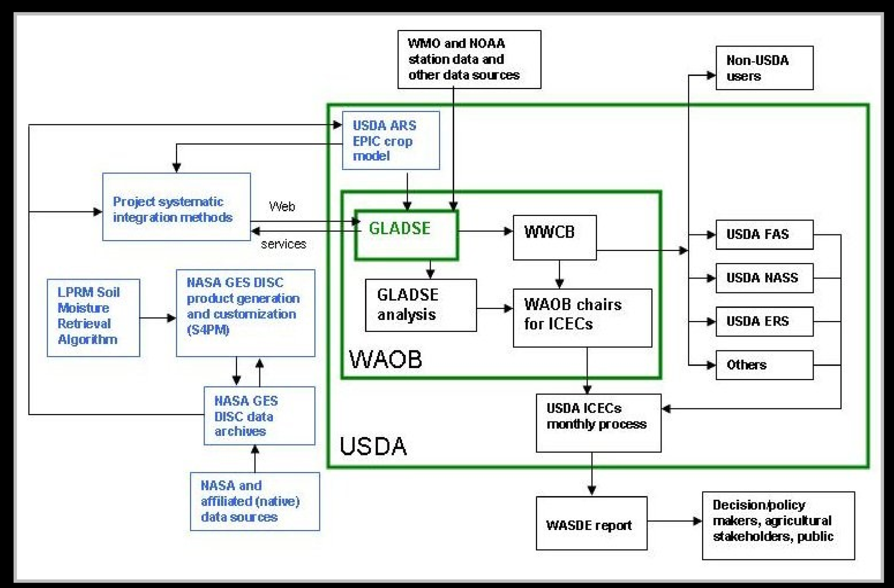
## Introduction

A primary goal of the U.S. Department of Agriculture (USDA) is to expand markets for U.S. agricultural products and support global economic development. The USDA World Agricultural Outlook Board (WAOB) supports this goal by coordinating monthly World Agricultural Supply and Demand Estimates (WASDE) for the U.S. and major foreign producing countries. Because weather has a significant impact on crop progress, conditions, and production, WAOB prepares frequent agricultural weather assessments, in a GIS-based, Global Agricultural Decision Support Environment (GLADSE). The main goal of this project, thus, is to improve WAOB's estimates by integrating NASA remote sensing soil moisture observations and research results into GLADSE (See diagram below). Soil moisture is currently a primary data gap at WAOB.




Operational flow diagram of GLADSE and other USDA entities and of project components (in blue).

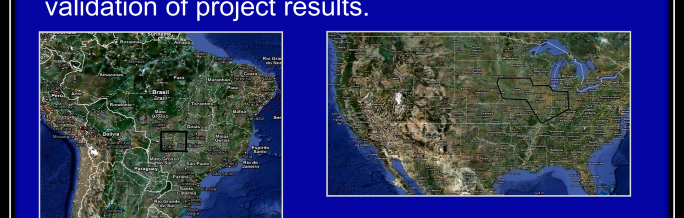
Objectives:

- To integrate, as seamlessly as possible, WAOB-customized Land Parameter Retrieval Model (LPRM) soil moisture data and an LPRM-enhanced EPIC (Environmental Policy Integrated Climate) crop model into the operational WAOB GLADSE and, thus, to improve the WAOB's decision-making process.
- To leverage existing Web services at the GES DISC to mediate and facilitate the integration of project products into GLADSE.
- To systematically and rigorously evaluate and benchmark the impact of the integration of NASA data and technologies on GLADSE forecasts with three of the major agricultural regions worldwide for which WAOB has responsibility.
- To implement a detailed plan for transferring the expected successful project results to, and their sustained long-term use by, WAOB.

## Analog Year Comparisons for Crop Yield Forecasts

### Study areas

2 major agricultural regions worldwide for validation of project results.



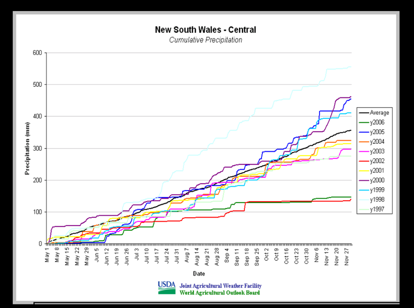
Southern Brazil (Soybeans) | U.S. Midwest (corn, soybeans)

During the past two decades, Brazil soybean production has surged, increasing from about 16 million MT in 1990/91 to nearly 70 million MT in 2009/10. This increase in production has enabled Brazil to become a major soybean exporter. In this study, we focus on Parana, historically one of the largest soybean-producing states in Brazil, located in the southern semitropical part of the country.

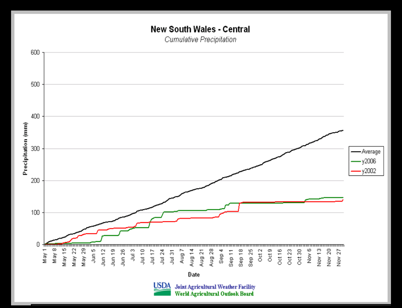
The United States is the largest corn producer and exporter in the world. Located in the heart of the Corn Belt, Iowa is the largest corn producing state, accounting for about 19% of domestic production annually. The climate in Iowa is characterized as temperate, but weather extremes can significantly affect corn production.

### Methods

Project benchmarking is based on retrospective analyses of WAOB's analog year comparisons, between a given year and historical years with similar weather patterns. Below is an example from New South Wales, Australia.




2006 is the target year…
…what year(s) are similar?




2006 is the target year…
… 2002 is an analog year.

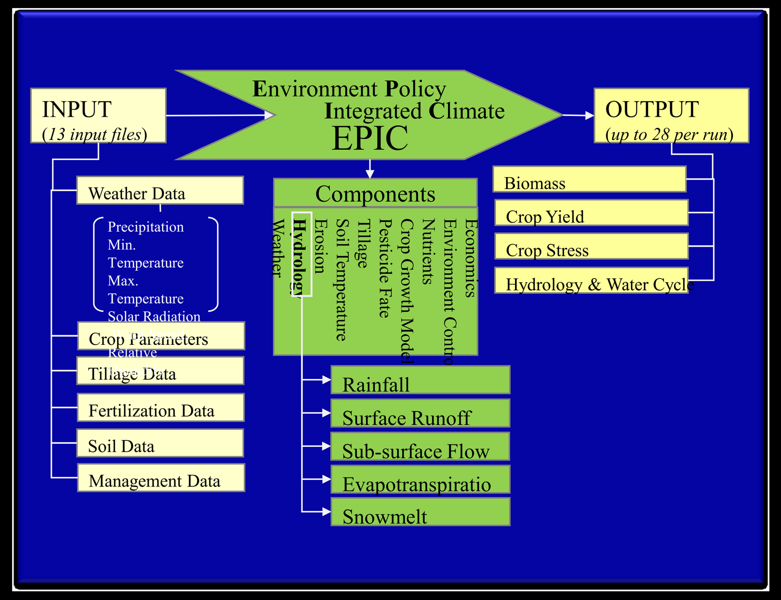
| Actual Winter Wheat Yields | |
|---|---|
| Year | ΔYield from Trend (ton/ha) |
| 2006 | -1.63 |
| 2005 | -0.05 |
| 2004 | -0.51 |
| 2003 | -0.42 |
| 2002 | -1.38 |
| 2001 | 0.15 |
| 2000 | 0.00 |
| 1999 | 0.40 |
| 1998 | -0.01 |
| 1997 | -0.03 |

In 2006, drought in New South Wales threatened a reduction in winter wheat yields estimated by WAOB meteorologists to be similar to that of 2002, based on analog analyses of precipitation time series. Indeed, following the harvest, wheat yields were found to be well below the trend. Although the weather was similar in both years, yields differed. This variability can be attributed to a number of factors, including subtle differences in the timing of the rainfall, varieties of wheat planted, and amount of wheat grazed rather than harvested.

Historically, WAOB meteorologists have identified analog years through visual inspection of these data. Although such techniques have been beneficial in identifying years with similar weather patterns, the qualitative nature of these analyses sometimes precludes the definitive identification of the best analog year, especially when multiple potential analog years exist. A goal of this study is to introduce a more rigorous, statistical approach for identifying analog years. Several quantitative methods are currently being explored, including a combination of correlation coefficients, differencing techniques, and weighting functions.

## Data – Surface, Satellite, Model

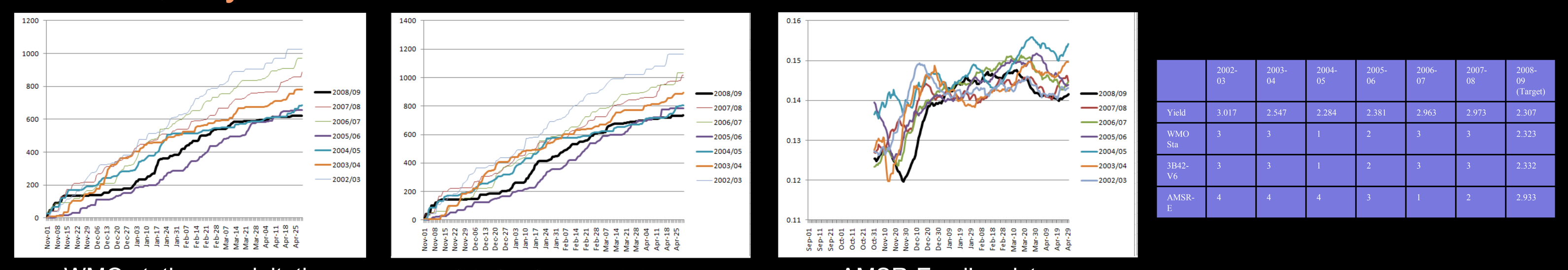
- Station-based precipitation: Regional time series are derived by averaging daily cumulative precipitation from multiple surface observing stations distributed evenly throughout each study area. Parana, Brazil – 6 stations from World Meteorological Organization (WMO) network; Iowa, U.S. – 8 stations from NOAA/NWS Cooperative Observer Program (COOP) network; Sioux Co., Iowa – 4 stations from NOAA/NWS COOP network.
- Crop yield: Brazil – annual Parana soybean statistics obtained from Instituto Brasileiro de Geografia e Estatística; U.S. – annual county- and state-level corn statistics for Iowa obtained from USDA National Agricultural Statistics Service (NASS).
- TRMM Multi-satellite Precipitation Analysis (TMPA; 3B42-V6) (Huffman et al., 2007): 0.25-deg; daily (averaged from 3-hourly); source data sets merged (TRMM, AMSR-E, SSM/I, others); temporal coverage 1998-present.
- AMSR-E surface soil moisture (AE_Land3) (Njoku et al., 2003): 0.25-deg; daily (asc., desc.); EOS Aqua; temporal coverage 2002 (June)-present.
- Root-zone soil water (RZSW) from EPIC (William et al., 2006, 2008): Comprehensive crop growth and environmental assessment model developed by the USDA-ARS. Provides continuous daily simulation of the growth of many crops, soil moisture profile, hydrology, erosion, sedimentation, and management practices and their impacts on crop growth and environment sustainability.




Huffman et al., 2007. The TRMM Multi-satellite Precipitation Analysis: Quasi-global, multi-year, combined-sensor precipitation estimates at fine scale. *J. Hydrometeor.*, *8*(1), 38-55.
Njoku et al., 2003, Soil moisture retrieval from AMSR-E, *IEEE Trans. Geoscience and Remote Sensing, 41*(2), 215-229.
Williams et al., 2008, Agricultural Policy / Environmental eXtender Model Theoretical Documentation v. 0604.
Williams et al., 2006, EPIC User Guide v. 0509.

## Analog Year Analyses Results

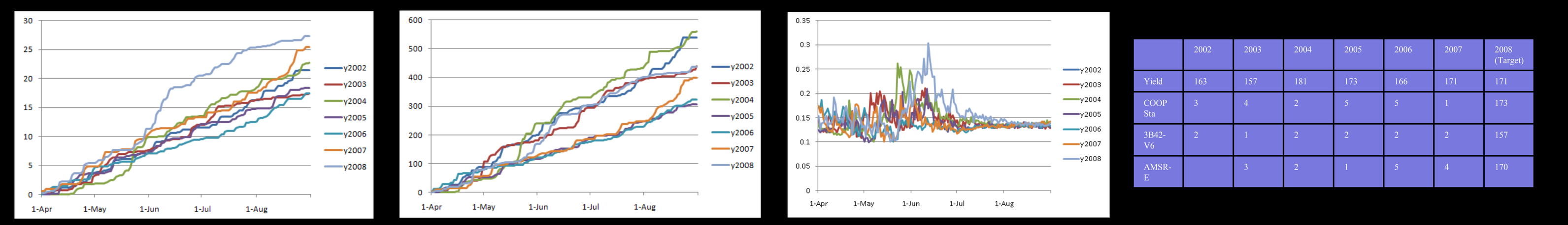
### Parana, soybeans



WMO station precipitation | 3B42-V6 precipitation | AMSR-E soil moisture

- WMO station and 3B42-V6 precipitation data performed very well; both resulted in the same analog year (2004-05) for the target year of 2008-09.
- AMSR-E soil moisture-based analogs are poor.

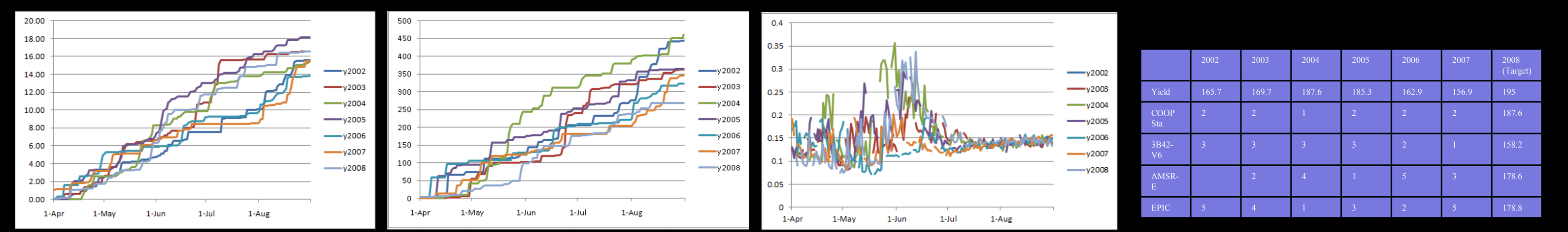
### Iowa, corn



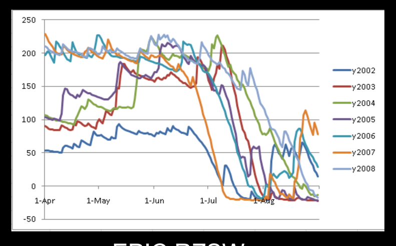
COOP station precipitation | 3B42-V6 precipitation | AMSR-E soil moisture

- COOP station and AMSR-E soil moisture data performed well, with best analog years of 2007 and 2005, respectively, for the target year of 2008. Difference in historical yields between 2007 and 2005 is only 2 bu/ac.
- 3B42-V6-based analogs are poor, due possibly to data issues, as suggested in comparing with a third source of precipitation from NOAA High Plains Regional Climate Center.

### Sioux Co., Iowa, corn



COOP station precipitation | 3B42-V6 precipitation | AMSR-E soil moisture

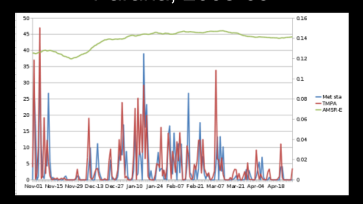


EPIC RZSW

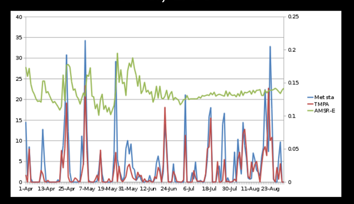
- COOP station, AMSR-E soil moisture, and EPIC RZSW data performed comparably, with best analog years of 2004, 2005, and 2004, respectively, for the target year of 2008. COOP station data projected yield was closest to target year yield.
- 3B42-V6-based analogs are poor; additional investigations needed.

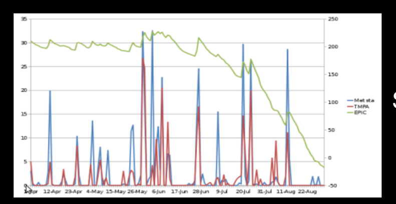
## Analog Year Analyses Results (cont.)

Parana, 2008-09



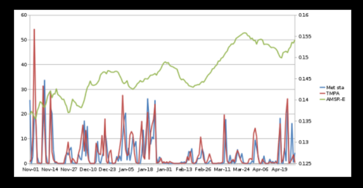
Iowa, 2007

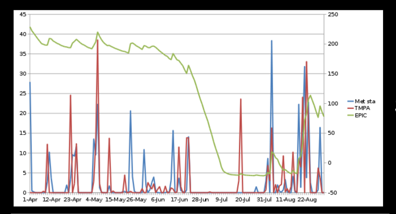




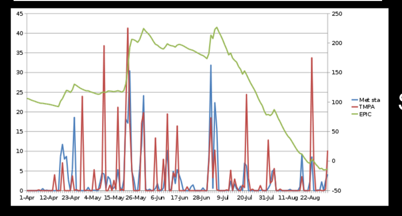
Sioux Co., Iowa, 2008

Parana, 2004-05





Sioux Co., Iowa, 2007



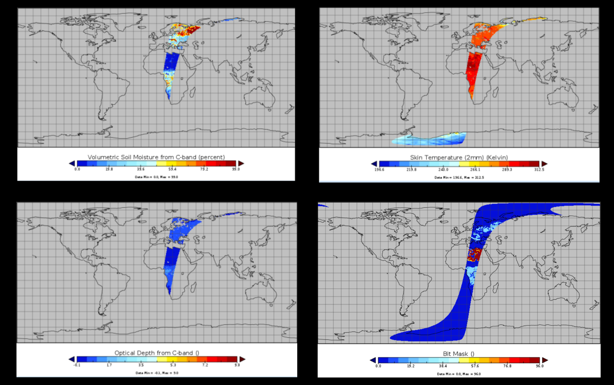
Sioux Co., Iowa, 2004

## Summary

- Satellite data are complementary to weather station data, in identifying analog years, although the performance of satellite precipitation and surface soil moisture varied with location.
- Though preliminary, these results point to the possibility of "calibrating" the analog analysis methodology in station-rich areas, to be then applied in station-poor areas of the world.
- Use of retrospective analog analysis as a metric for assessing the effect of integrating NASA data into WAOB seems feasible.

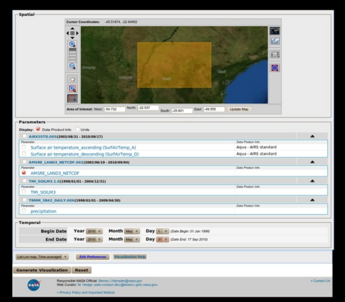
## Project Status – What Else and What's Coming

### LPRM L2, L3 production

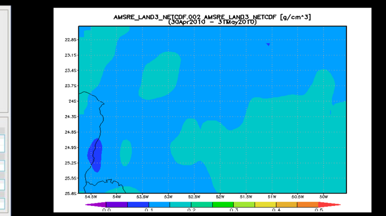



- Provide global soil moisture with high temporal resolution and 0.25 degree spatial resolution, for the top few cm of the soil column (Owe et al., 2008).
- Extensively validated; has an accuracy of ~0.06 $m^3\ m^{-3}$ for sparse to moderate vegetated regions (De Jeu et al., 2008).
- ***L2 product to be released ~early 2011.***
- ***L3 gridded daily product to be released ~late spring 2011.***

### Giovanni-Soil Moisture (Berrick et al., 2009)

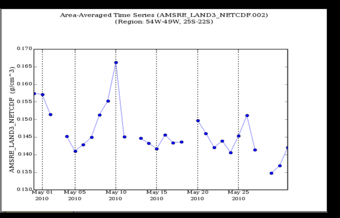


Giovanni user interface



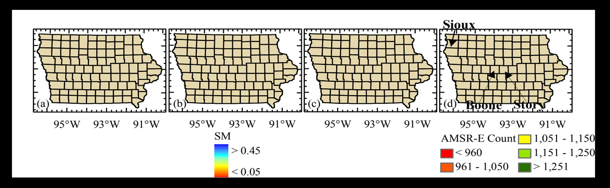
Lat-lon map (averaged over May 1-31, 2010 of a region in Parana, Brazil

Time series (May 1-31, 2010) of a region in Parana, Brazil

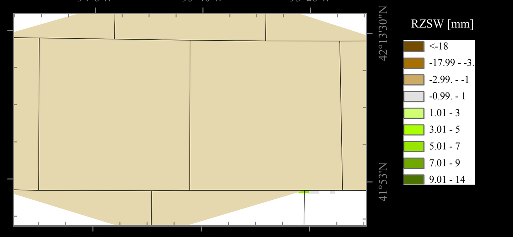



- ***Operational release ~spring 2011.***
- ***Initial parameters include LPRM soil moisture, AMSR-E soil moisture, TMPA precipitation, and AIRS surface temperature.***

### Assimilating AMSR-E into EPIC (Mladenova et al., 2010)




Surface soil moisture ($m^3/m^3$) from AMSR-E (a-original, b-scaled) and EPIC (c) for June 1-3, 2004, and number of available AMSR-E descending overpass for 2003-2008 (d).




Estimated average change in root zone soil water (RZSW), after assimilating AMSR-E soil moisture into EPIC for 2005 for two counties in Iowa. White areas represent non-agricultural areas.

Average change in RZSW after assimilation is ~ +/-20 mm (model runs over 5 counties), relative to RZSW w/o assimilation of up to 260-280 mm.

Berrick et al., 2009, Giovanni: a Web services workflow-based data visualization and analysis system. *IEEE Trans. Geosci. Remote Sens.*, *47*(1), 106-113.
De Jeu et al., 2008, Global soil moisture patterns observed by space borne microwave radiometers and scatterometers. *Surv. Geophys, 29,* 399-420, doi: 10.1007/s10712-008-9044-0.
Mladenova et al., 2010, Potential for improved crop yield prediction through assimilation of satellite-derived soil moisture data. Proc. Remote Sensing and Hydrology Symp. 2010, Jackson Hole, WY.
Owe et al., 2008, Multisensor historical climatology of satellite-derived global land surface moisture. *J. Geophys. Res., 113,* F01002, doi:10.1029/2007JF000769.

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